

WO 2005/073685

**10/566089**

PCT/GB2005/000358

**IAP20 Rec'd PCT/PTO 27 JAN 2006**

1

**LINEAR PRESSURE SENSOR****Background of the Invention****1. Field of the Invention**

The present invention relates to sensors, in particular pressure sensors.

**2. Description of the Related Art**

Pressure sensors have many practical applications and may be used to detect that a person is sitting in a car seat or to detect an obstacle in the path of a mechanical moving part. For example, a motorised garage or lift door may be equipped with a pressure sensor on the leading edge. When an obstacle is detected, an input signal may be provided to the motor control from the sensor, which in turn may trigger the motor control to reverse the direction of motion of the moving door to prevent damage to the door and/or the obstacle. Applications may be safety-critical.

Different types of pressure sensor are suitable for such an application. These include pneumatic based sensors that utilise a tube and an air pressure sensor arranged to detect a change in the internal tube pressure. Wire based sensors utilise conductive strips located within a soft component and are arranged to detect contact between the strips. Optical based sensors utilise a hollow, flexible soft component, light transmission and a receiver arranged to detect light occlusion. Field based sensors utilise an antenna to establish an electrical field along the leading edge, arranged to detect the presence of a conductive object. Another type of sensor utilises a flexible surface incorporating push-button control switches, formed from layered conductive plastic or foil. A common problem with these types of sensors is that they display unsatisfactory durability.

WO 2005/073685

PCT/GB2005/000358

## 2

Applications for the above types of sensor are restricted by the limited ability of pneumatic, wire, optical and push-button switch based sensors to accommodate bends or curves around tight radii, and the difficulty of operating a field based sensor in a changing environment.

**Brief Summary of the Invention**

According to a first aspect of the present invention there is provided a linear sensor comprising electrically conductive textile fibres and electrically insulating textile fibres, wherein said sensor further comprises at least two conductive elements formed from said electrically conductive fibres, and said insulating textile fibres are spaced apart to allow electrical conduction between two conductive elements under the application of pressure.

In one embodiment, the sensor comprises a first conductive element, a second conductive element and a third conductive element, said first conductive element disposed between and electrically insulated from said second and third conductive elements, said sensor configured to allow electrical connection between said first conductive element and one of said second and third conductive elements.

In a preferred embodiment the sensor said at least two conductive elements comprise a first conductive element having electrically conductive textile fibres extending along at least a portion of the length of said sensor; and a second conductive element having electrically conductive textile fibres extending along at least said portion of the length of said sensor, and said sensor further comprises a third conductive element extending along at least said portion of the length of said sensor, wherein said third conductive element is electrically insulated from said first and second conductive

WO 2005/073685

PCT/GB2005/000358

## 3

elements over said portion of the length of said sensor, and said third conductive element is electrically connected at one end to only one of said first conductive element and said second conductive element.

According to a second aspect of the present invention there is provided a linear sensor comprising electrically conductive textile fibres and electrically insulating textile fibres: said sensor comprising a first conductive element having electrically conductive textile fibres extending along the length of said sensor; a second conductive element having electrically conductive textile fibres extending along the length of said sensor and surrounding said first conductive element; and electrically insulating textile fibres configured to (i) separate said two electrically conductive elements when no pressure is applied to said sensor and (ii) allow electrical conduction between said two conductive elements under the application of pressure.

**Brief Description of the Several Views of the Drawings**

*Figure 1* shows an end of a sensor **101** having a construction utilising textile fibre;

*Figure 2* shows a cross-section of a second linear sensor **201**;

*Figure 3* shows an electrical arrangement for linear sensor **201** of *Figure 2*; and

*Figures 4 and 5* illustrate an application of a linear sensor.

**Best Mode for Carrying Out the Invention*****Figure 1***

The present invention provides a linear sensor having a construction

WO 2005/073685

PCT/GB2005/000358

## 4

utilising textile fibre. The sensor is suitable for use in linear position sensing applications.

Many textile structures may be used to produce a strip or braid on which to base the sensor. Such textile structures may be produced substantially in one operation, using conventional textile manufacturing techniques, such as weaving, knitting or braiding. The incorporation of elastic fibres, such as Lycra <sup>™</sup> or Elastane <sup>™</sup> into the textile structure assists the structure to return substantially to its original shape after the application of pressure.

*Figure 1* illustrates a construction of textile structure **101**. The structure **101** comprises a first conductive element **102**, which extends substantially centrally along and through the length of the structure **101**. In this example, conductive element **102** is fabricated from a bundle of carbon impregnated nylon conductive textile fibres **103**, such as F901, available from Shakespeare Inc. A second conductive element, **104** is braided around the central conductive element **102**. The second conductive element comprises similar carbon impregnated nylon conductive textile fibres **105** and insulating fibres **106**. The diameter of the insulating fibres **106** is greater than the diameter of the conductive fibres **105**, such that, in the no pressure applied condition, the second conductive element **104** does not make electrical contact with the central conductive element **102**. However, within the structure of the braided conductive element **104** the fibres are sufficiently spaced to allow electrical contact between the second conductive element **104** and the central conductive element **102** when pressure is applied to the textile structure **101**. Using conductive fibres and insulating fibres having different diameters is only one way to achieve this functionality.

WO 2005/073685

PCT/GB2005/000358

## 5

The structure **101** further comprises a flexible, insulating, soft foam sheath **107** or sleeve surrounding the second conductive element **104**. The sheath **107** serves to provide protection for the structure **101** and facilitates the application of pressure to individual conductive fibres within second conductive element **104**. However, sheath **107** is arranged to be stripped away from the structure **101**, to allow electrical connection to be made with a conductive element of the structure **101**. According to the present example, first conductive element **102** and second conductive element **104** are concentric.

Thus, the present invention provides a linear sensor having a first conductive element and a second conductive element normally spaced apart but arranged to make contact under applied pressure. The linear sensor may take a string-life form.

In a preferred embodiment of linear sensor, at least the second conductive element is constructed such that the fibres therein extend in a direction that is not along the same axis of the length of the linear sensor. This feature facilitates local stretching, which in turn facilitates bending and flexing of the sensor without causing unwanted contacts between the inner and outer conductive elements. Local stretching is further facilitated by the inclusion of elastic fibres, for example Lycra<sup>™</sup> fibres, which help to return the structure to its original shape following the application of pressure thereto.

**Figure 2**

A cross-section of a linear sensor **201** according to the present invention is shown in *Figure 2*. The sensor **201** comprises an insulating element **203**, in this example polyurethane plastic. A first conductive

WO 2005/073685

PCT/GB2005/000358

## 6

element **204** comprising conductive fibres **205** surrounds the insulating element **203**. A second conductive element **206** comprising conductive fibres **207** and insulating fibres **208** surrounds the first conductive element. The diameter of the insulating fibres **208** of second conductive element **206** is greater than that of the conductive fibres thereof. The sensor **201** also comprises a third, central conductive element **202** located within the insulating element **203** such that it is surrounded by said insulating element and thereby insulated from the first conductive element **204**. A sheath **209** surrounds the second conductive element **206**. Thus, the base structure of linear sensor **201** is similar to the textile structure **101** shown in *Figure 1*, but with the addition of the further inner conductive element **202**.

In the present embodiment, the central conductive element **202** comprises conductive textile fibres of a similar type to those contained in the first and second conductive elements, but in an alternative embodiment the central conductive element comprises metallic wires.

Pressure applied to the sheath **209** causes it to deform and push conductive fibres **207** of second conductive element **206** inwards towards conductive fibres **205** of first conductive element **204**, until at a threshold pressure electrical contact is established between the conductive fibres **205**, **207** of the first and second conductive elements **204**, **206**. Thus, the insulating fibres generally insulate the first conductive element from the second conductive element unless an applied pressure forces said conductive elements together.

It should be noted that the function of the insulating element **203** differs from that of the insulating fibres **208** in that it continues to insulate the central conductive element **202** from the first conductive element **204** even when pressure is applied.

WO 2005/073685

PCT/GB2005/000358

## 7

The central conductive element 202 provides a separate conductor that may be used to establish an electrical contact at each end of one of the first and second conductive elements 204, 206, to allow an electrical potential to be established across the ends of the conductive element.

**Figure 3**

An electrical arrangement for linear sensor 201 is illustrated in *Figure 3*. By use of central conductive element 202, both +V and 0V electrical connections are made at one end of the linear sensor 201. A first electrical connection is made by connecting +V to the second conductive element 206. A second electrical connection is made by connecting 0V to the third conductive element 202. A third connection is made to second conductive element 204, which allows a voltage measurement reading to be taken.

At the other end to the first, second and third electrical connections, a terminating piece 301 provides an electrical connection between second conductive element 206 and the central conductive element 202. Thus, the central conductive element 202 acts as a link to facilitate the application of an electrical potential across the linear sensor 201.

An electrical potential is applied across one of the first and second conductive elements of linear sensor 201, in this example across second conductive element 206. Under sufficient applied pressure, electrical contact is made between the second and first conductive elements, whereafter the linear sensor 201 acts substantially as a potentiometer. A "wiper" voltage reading may then be taken at the third electrical connection to first conductive element 204. Such a voltage reading provides an indication of the position of the centre of contact between the first and second conductive elements 204, 206 along the length of the linear sensor

WO 2005/073685

PCT/GB2005/000358

8

**201.**

If the central conductive element **202** is omitted from the structure of the linear sensor **201**, the sensor may act as a switch, with two electrical connections, one each made to first conductive element **204** and second conductive element **206**. However, the electrical connection provided by central conductive element **202** provides the described potentiometer function and enables a configuration arranged to provide an indication of the position of a mechanical interaction along the linear sensor. It should be noted that in each embodiment, the sensor is a linear sensor in that it has a length which is substantially longer than its other dimensions.

A linear sensor according to the present invention may be connected to a data processing means, for example a PIC micro-controller, such as PIC16F71 incorporating an A to D converter. The data processing means may receive frequent voltage measurements taken from the linear sensor. This data may then be encoded and used to communicate with a separate device, such as a portable MP3 player or pendant mobile phone.

#### ***Figures 4 and 5***

An application of a linear sensor is illustrated in *Figures 4 and 5*. A linear sensor is incorporated into a lanyard **401**, or neck-strap, on which a portable MP3 player **402** is worn around the neck of a user **501**. The lanyard **401** has characters or symbols **403** printed on the surface, representing controls. By stroking and/or pressing the characters or symbols **403**, the user **501** can interact with the linear sensor. Control data, processed from positional data from the sensor is sent to the MP3 player **402** via the micro-controller mounted in interface connector **404**. The neck-strap **401** may thus be used to control functions of the MP3 player **402** such



**WO 2005/073685****PCT/GB2005/000358****9**

as play functions and volume control.